AD NUMBER
AD483424
LIMITATION CHANGES

TO:

Approved for public release; distribution is unlimited.

FROM:

Distribution authorized to U.S. Gov't. agencies only; Administrative/Operational Use; 15 MAY 1966. Other requests shall be referred to Bureau of Ships, Washington, DC 20360.

AUTHORITY

BUSHIPS ltr 27 Nov 1967

INTERIM DEVELOPMENT REPORT

FOR

GAS SOLID-STATE RECEIVER PROTECTOR
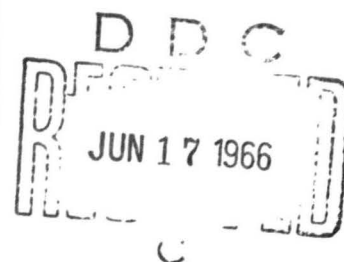
AT S-BAND

16 February 1966 to 15 May 1966

Department of the Navy
Bureau of Ships

Contract No. NObsr 95008

MICROWAVE

ASSOCIATES,

INC.

Burlington, Massachusetts

D D C

JUN 1 7 1966

INTERIM DEVELOPMENT REPORT

FOR

GAS SOLID-STATE RECEIVER PROTECTOR

AT S-BAND

This Report Covers the Period 16 February 1966 to 15 May 1966

MICROWAVE ASSOCIATES, INC.
Burlington, Massachusetts

Navy Department Bureau of Ships - Electronics Divisions

Contract NObsr 95008 Code 681A1D 26 July 1965

Project Serial Number SR008-0301

Task 9386

Prepared by

John Gregory
Development Engineer

Approved by

Fred A. Jellison
Section Manager

TABLE OF CONTENTS

ABSTRACT

This report discusses the experimental results obtained for single stage and dual stage varactor limiters. It is shown that for a complete Pre-TR-TRL passive receiver protector, insertion losses below .7 dB and forward bias isolations of at least 36 dB are possible. Continued developmental efforts have led to an improved ignitorless gas limiter protector that has breakdown and leakage performance characteristics comparable to a tube containing a dc keep alive operating at 100 microamperes current.

i

1. Purpose

   The purpose of this program is to design, develop and life test a passive receiver protector of 100 kW peak power at S-band with low loss and fast recovery time that can handle overloads in power of 3 megawatts peak and provide protection for low noise amplifiers. The device shall be reliable and capable of long life - 2000 hours minimum.

   In addition to the basic requirement already listed the following design goals are to be attained:

1.	Frequency	2.9-3.1 gc
2.	Pulse Width	30 μsec max.
3.	Average Power	15 kW max.
4.	VSWR	1.4 max.
5.	Insertion Loss	0.8 dB max.
6.	Recovery Time	15 μsec max.
7.	Spike Leakage	0.05 erg max.
8.	Flat Leakage	30 mW max.
9.	Length	6" max.

2. General Factual Data

   A) Identification of Technicians

      During the period covered by this report, the following man-hours were applied toward the objectives of the program:

Name	Job Title	Hours Contributed
John Gregory	Development Engineer	440
Fred Jellison	Section Manager (TR Engineering)	34
Robert Dunn	Engineer	19

B) Introduction

Modern radar technology has placed on the receiver protector a performance burden not achievable by the conventional TR tube. In particular, the introduction of low noise amplifiers (LNA) such as tunnel diode amplifiers, parametric amplifiers and masers, as first stages of the receiver, demands a transmitter leakage reduction not compatible with the gas TR tube art. These ultra-sensitive receiver elements are particularly sensitive to the random spike leakage bursts normally associated with TR switches depending on a gaseous plasma for the switch action.

This program is basically intended to develop a receiver protector suitable of protecting the new LNA's while simultaneously being capable of withstanding high power surges and introducing minimal insertion loss into the radar system. The device must also be passive, reliable, and capable of long life.

C) Basic Description of Receiver Protector

The general design approach consists of these four elements, combined and optimized in one package:

        A. A high power pre-TR (gas).

        B. A low loss limiter protector (gas).

        C. A medium power waveguide limiter (semiconductor).

        D. A low power waveguide limiter (semiconductor).

3. Detailed Factual Data

A) Introduction

The experimental work to be performed in this program consists of three tasks. These tasks are: (1) development of a gas limiter protector exhibiting constant gap firing characteristics without an external ignitor, (2) development of a dual stage limiter, and (3) a complete gas-solid state receiver protector package evaluation including life testing.

B) Evaluation of S-Band Limiter Mounts

A series of mounts with the configuration shown in Figure 1 have been

evaluated for insertion loss, isolation and Q. Evaluation consisted of determining optimum mount height (h_3) choke position (h_2) and protrusion depth (h_1). Both single and dual stage mounts were evaluated.

Typical results obtained with a single stage limiter are shown in Figure 2 where both VSWR and isolation are plotted as functions of frequency. These results obtained with a full height mount reveal a Q of 3.7 and a minimum isolation of 20 dB over the band of interest (2.9 to 3.1 GHz). At 3 GHz the insertion loss was about .05 dB.

Similar measurements made with a single stage, three quarter height mount produced the results shown in Figure 3. In this case there is a ten percent reduction in Q with again, a minimum isolation of 20 dB over the band. Further reductions in mount height, although resulting in a lower Q, did not provide sufficient isolation at the band edges.

Results obtained with a dual stage limiter are shown in Figure 4. Optimization of response was achieved by spacing two identically tuned limiters a quarter wave length apart. It is noted the maximum VSWR in the band of interest is 1.34 and isolation greater than 36 dB is achieved at the band edges. These results indicate that the low level design requirements for the limiter section of the gas-solid state receiver protector have been achieved.

The dual stage limiter was included in a complete package using existing pre-TR and TR tubes. The overall package insertion loss was .6 dB or less over the band and the VSWR was less than 1.4.

C) Ignitorless Gas Limiter Protector

a) Introduction

The second stage of the receiver protector is a gas discharge TR type tube. It serves to reduce the high leakage from the first stage to a value that can be safely handled subsequently by the limiter section. Since the purpose of this program is to develop a completely passive receiver protector the use of

an external power source for providing keep alive actions is precluded. In addition to being passive a device containing an intrinsic electron source would have the following advantages: (1) Elimination of noise generated by a dc glow discharge, (2) Elimination of the problems of shorted ignitors, (3) Elimination of dc ignitor induced clean-up or reduced life, (4) Complete standby protection.

Possible approaches to the development of an intrinsic keep alive scheme were discussed in the previous report[1] and it was indicated that the radioactive technique is the only feasible scheme. Preliminary data had indicated that a radioactive keep alive was equivalent in performance to a 25 microampere dc keep alive. During this quarter, however, additional developmental efforts appear to have resulted in significantly improved performance.

b) Experimental Results

An evaluation of the effectiveness of the intrinsic keep alive can be obtained by measuring the breakdown power. Direct comparison with breakdown measurements made with a dc keep alive reveals, then, an indication of the relative effectiveness of the radioactive scheme.

In Figure 5 are presented the breakdown data obtained with a tube containing a radioactive source and a tube identical in type to the former but with a dc keep alive. Both tubes were tuned for minimum VSWR at 3 GHz before testing. A vacuum system with a back-filling capability was used to vary the gas pressure in the tubes so that breakdown power could be measured at various fill pressures. The high power pulse was 1 microsecond wide at a repetition rate of 100 pulses per second. The breakdown power, P_b, is defined as that power level at which the leakage power abruptly drops to a lower value.

It is seen in Figure 5 that the data obtained with the RA keep alive behaves according to the well known Paschen Law. Between 5 and 12 Torr the breakdown power does not radically change with fill pressure. The curves obtained with dc keep alive currents of 50 and 100 microamperes appear to depart from the conventional Paschen curve. This behavior is explained by the tendency for the glow

discharge to diffuse into the gap region at lower pressures resulting in very high electron densities in the gap. Although the breakdown power is considerably lower in the low pressure range the insertion loss or keep alive interaction with low level signals would be excessive. Beyond 8 Torr there is little difference in the break- down power-pressure characteristics between a 100 microampere dc keep alive and the radioactive keep alive.

Another experiment was carried out to determine what, if any, relationship exists between observed breakdown power and spike energy for a given keep alive scheme. Results of this investigation are shown in Figure 6 where the observed breakdown power and spike energy are plotted as functions of fill pressure. The gas fill used was argon and spike energies were calculated from peak amplitude and 3 dB width measurements that were taken with a fast rise time sampling oscilloscope. The relationship between breakdown power and spike energy is obvious from these curves.

The energy distributions for radioactive keep alives and dc keep alives are shown in Figure 7. Curve A is the data obtained with the dc keep alive operating at 100 microamperes. Curves B and C were obtained with the radioactive keep alive the latter curve obtained at a fill pressure of 6 Torr to determine the pres- sure dependence of the spike distribution. From Figure 7 it is seen that the mean spike energy produced from the radioactive keep alive is about 2 dB below that produced from the dc keep alive operating at 100 microamperes. Both curves were taken with a fill pressure of 10 Torr. According to the data presented in Figure 5, at this pressure the 100 microampere keep alive has a lower breakdown power than does the radioactive keep alive. In view of this fact one would expect the spike energy for the dc keep alive to be lower than that of the radioactive keep alive as was indicated in the previous paragraph. The approximate mean spike energies for cases A, B and C respectively are 1.6 ergs, 1 erg, and .7 erg. It is em- phasized that these results were taken at a low pulse repetition rate of 100 pulses. per second and it is reasonable to expect that at higher repetition rates these values

may be appreciably reduced.

4. Conclusions

Experimental results indicate that a dual stage varactor limiter operating between 2.9 GHz and 3.1 GHz can be designed to provide a minimum of 36 dB isolation under forward bias conditions and a VSWR less than 1.4. In addition, the insertion loss of a complete Pre-TR-TRL passive receiver protector was measured to be no greater than .6 dB over th? frequency range.

An improved ignitorless gas limiter protector has been shown to be comparable with respect to spike leakage and breakdown power, to a conventional TR tube operating with a dc keep alive current of 100 microamperes.

PART II

Program for Next Interval

During the fourth quarter of this program the following tasks are planned:

1. Complete high power evaluations of prototype combinations receiver protector.

2. Fabricate and life test two complete passive receiver protectors.

-8-

PART III

Illustrations

Figure No.	Description
1	S-Band Single Stage Limiter Mount Configuration
2	VSWR and Isolation for Single Stage Limiter - Full Height
3	VSWR and Isolation for Single Stage Limiter - Three Quarter Height
4	VSWR and Isolation for Dual Stage Limiter
5	Breakdown Power vs. Pressure for DC and RA Keep Alives
6	Breakdown Power and Spike Energy vs. Pressure for RA Keep Alive
7	Leakage Spike Energy Distribution

References

1. Gregory, J. Interim Development Report for Gas Solid-State Receiver Protector at S-Band, 16 November 1965 to 15 February 1966, Contract NObsr 95008.
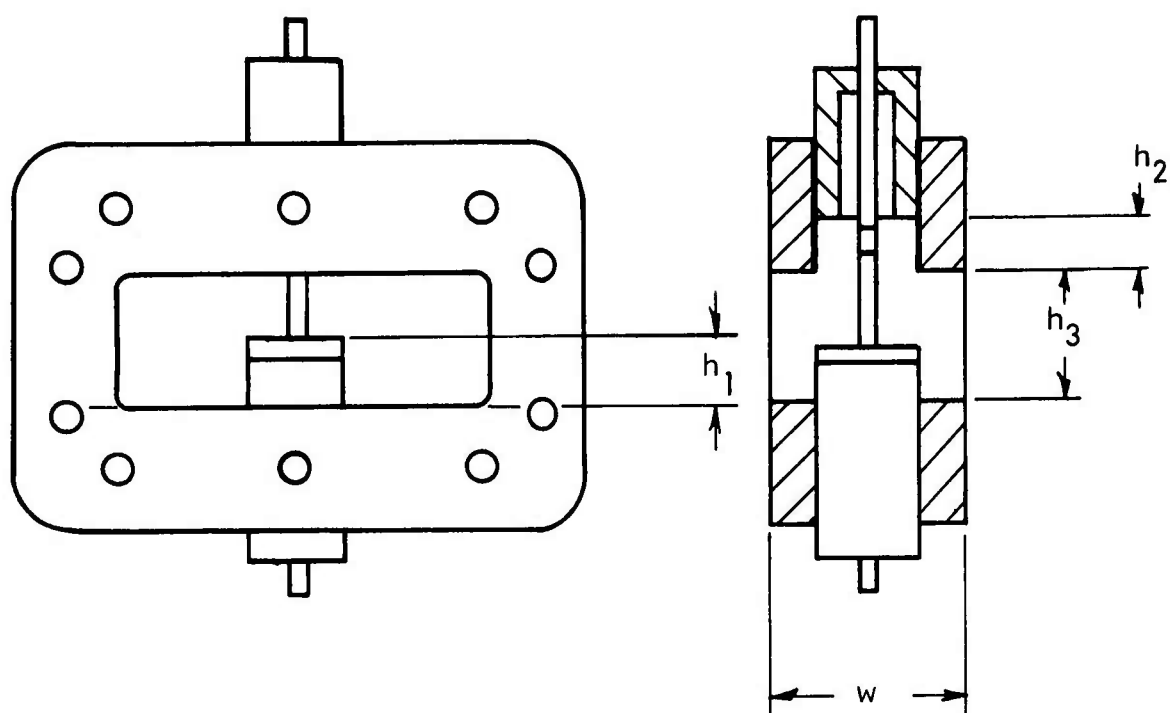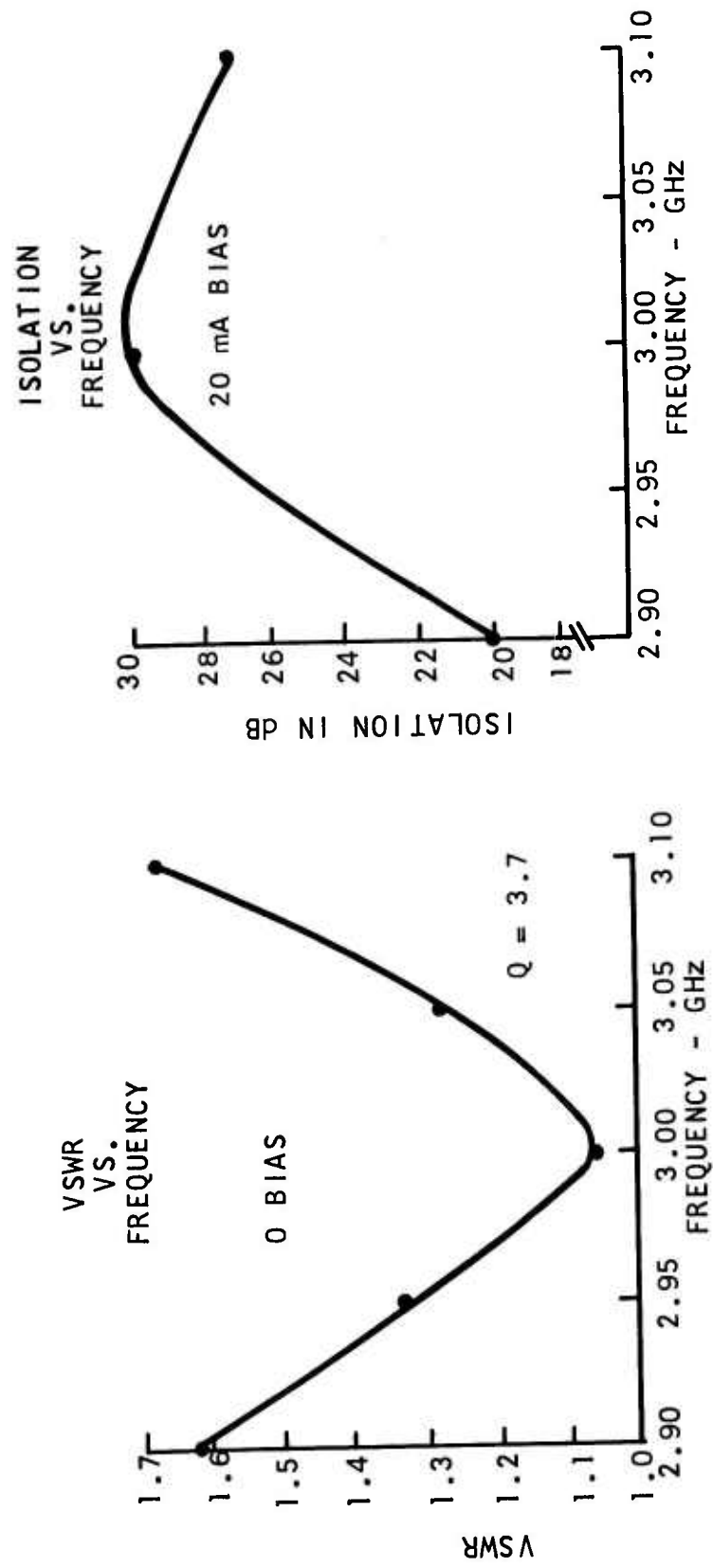
FIGURE 1
S-BAND LIMITER MOUNT CONFIGURATION

D-3513

ISOLATION
VS.
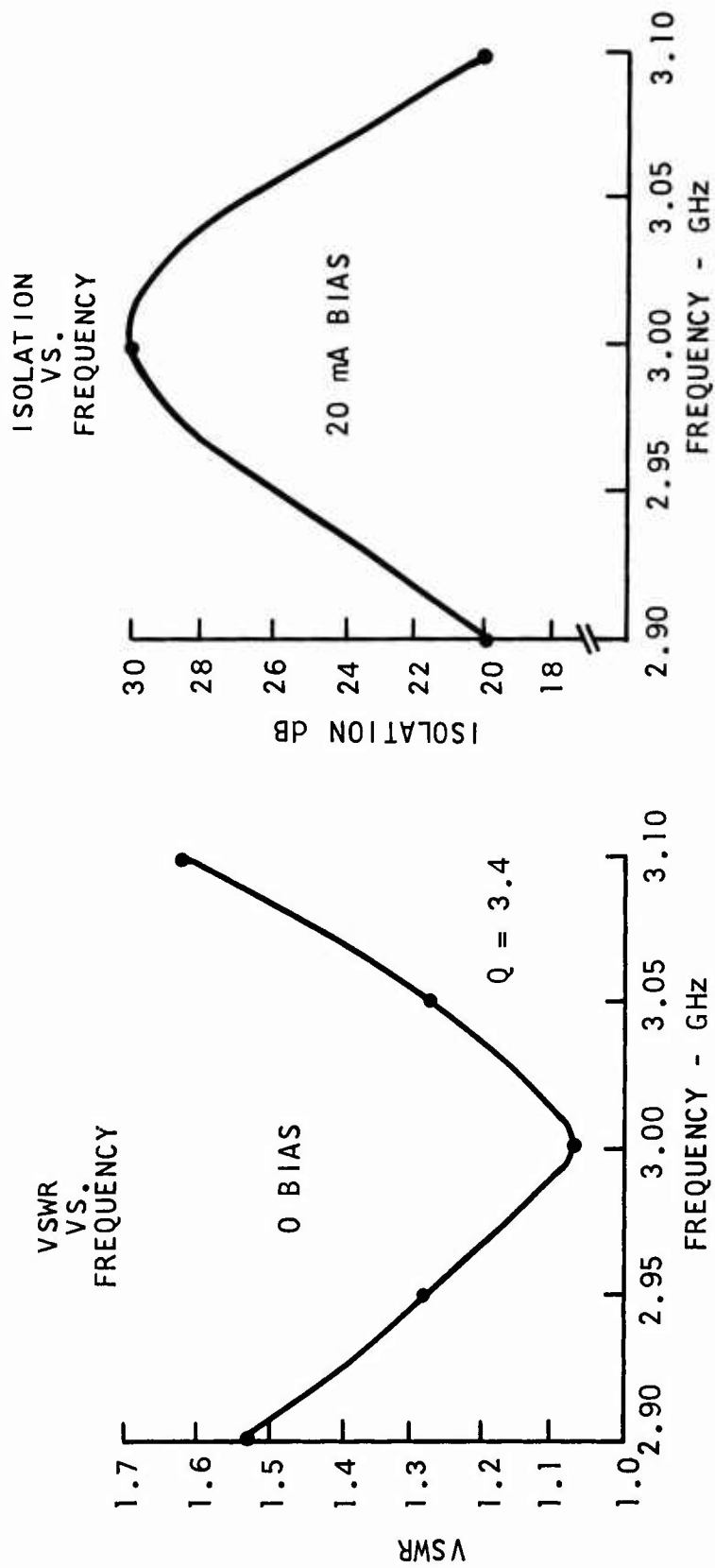FREQUENCY

20 mA BIAS

VSWR
VS.
FREQUENCY

0 BIAS

Q = 3.7

FIGURE 2

ZERO BIAS AND FORWARD BIAS CHARACTERIATICS OF SINGLE STAGE FULL HEIGHT
S-BAND LIMITER MOUNT

D-4233

FIGURE 3

ZERO BIAS AND FORWARD BIAS CHARACTERISTICS OF SINGLE STAGE THREE QUARTER HEIGHT
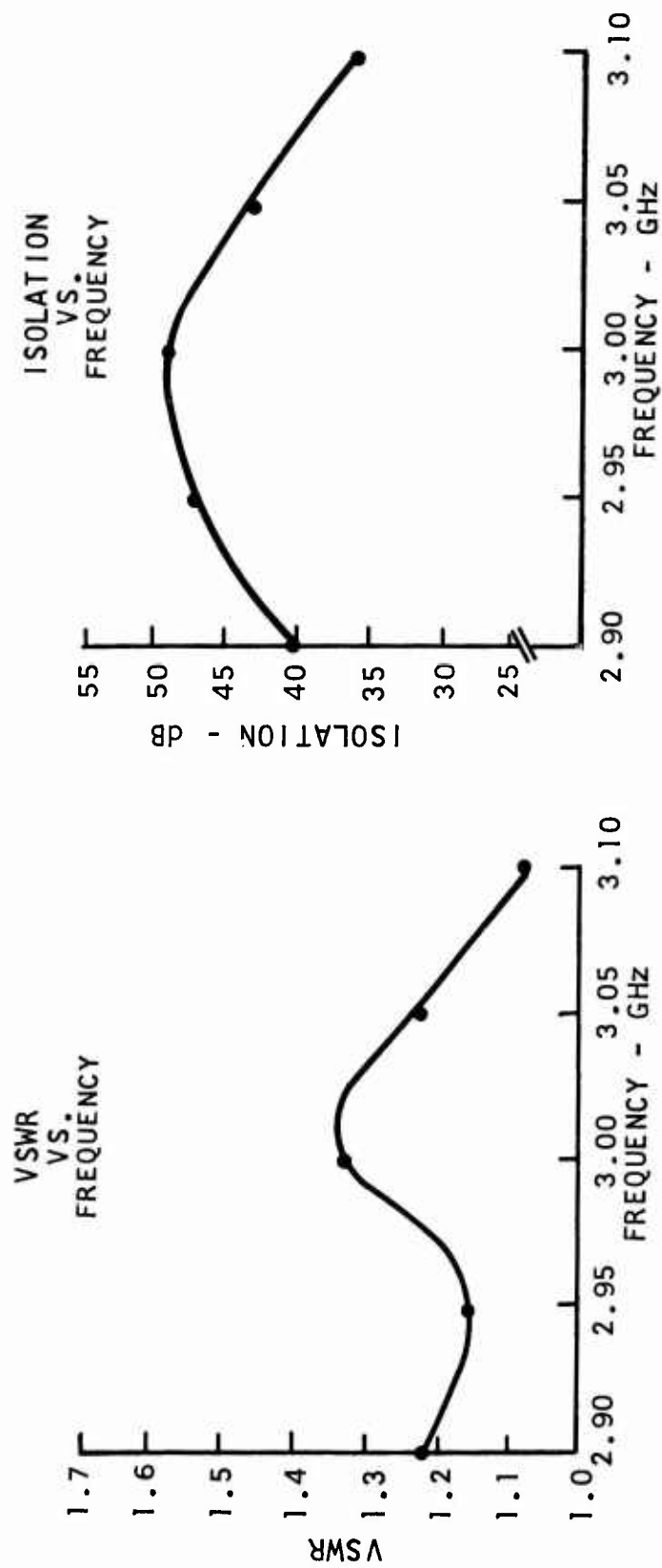S-BAND LIMITER MOUNT

D-4232

FIGURE 4

ZERO BIAS AND FORWARD BIAS CHARACTERISTICS OF A DUAL STAGE THREE QUARTER HEIGHT
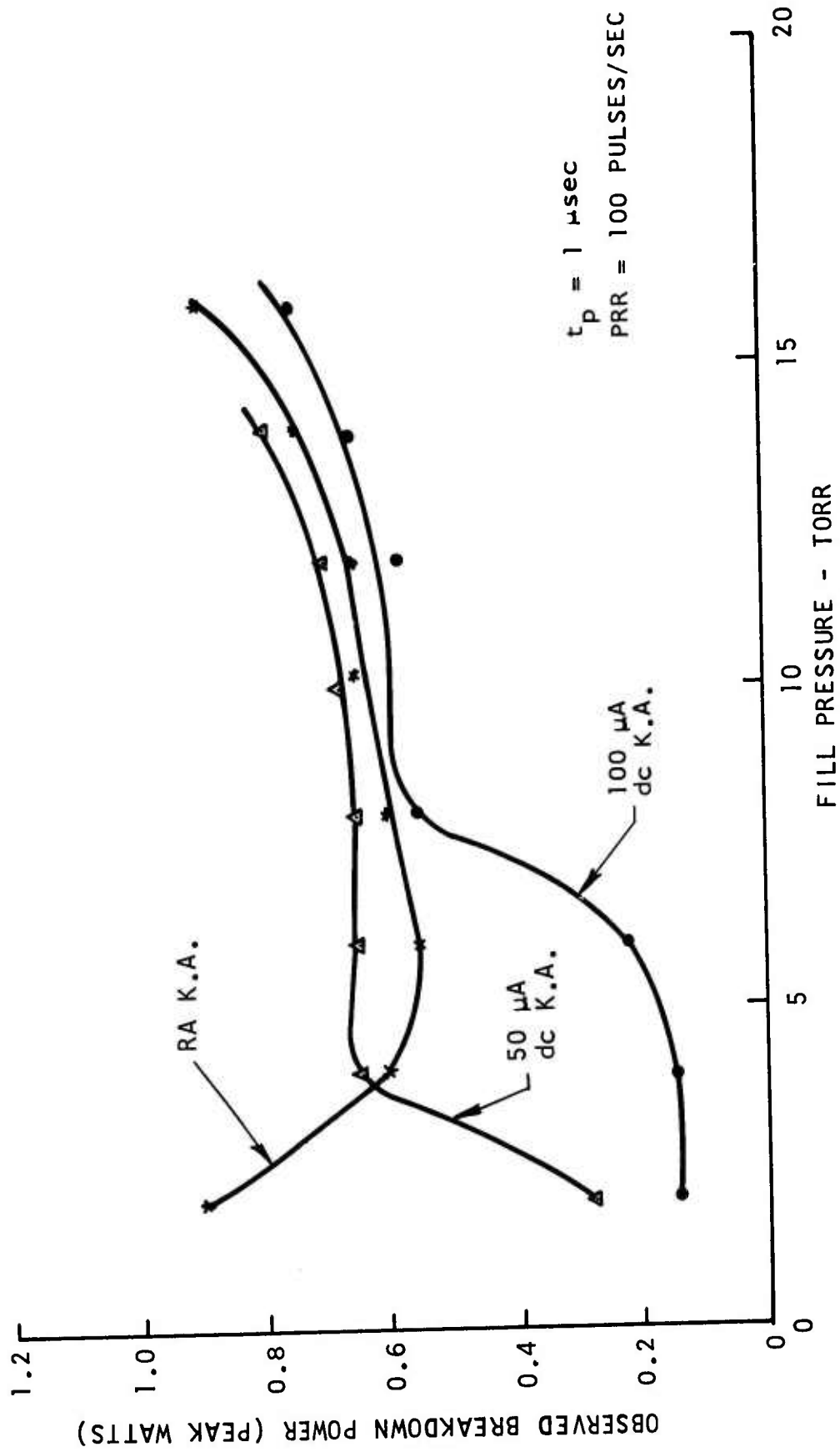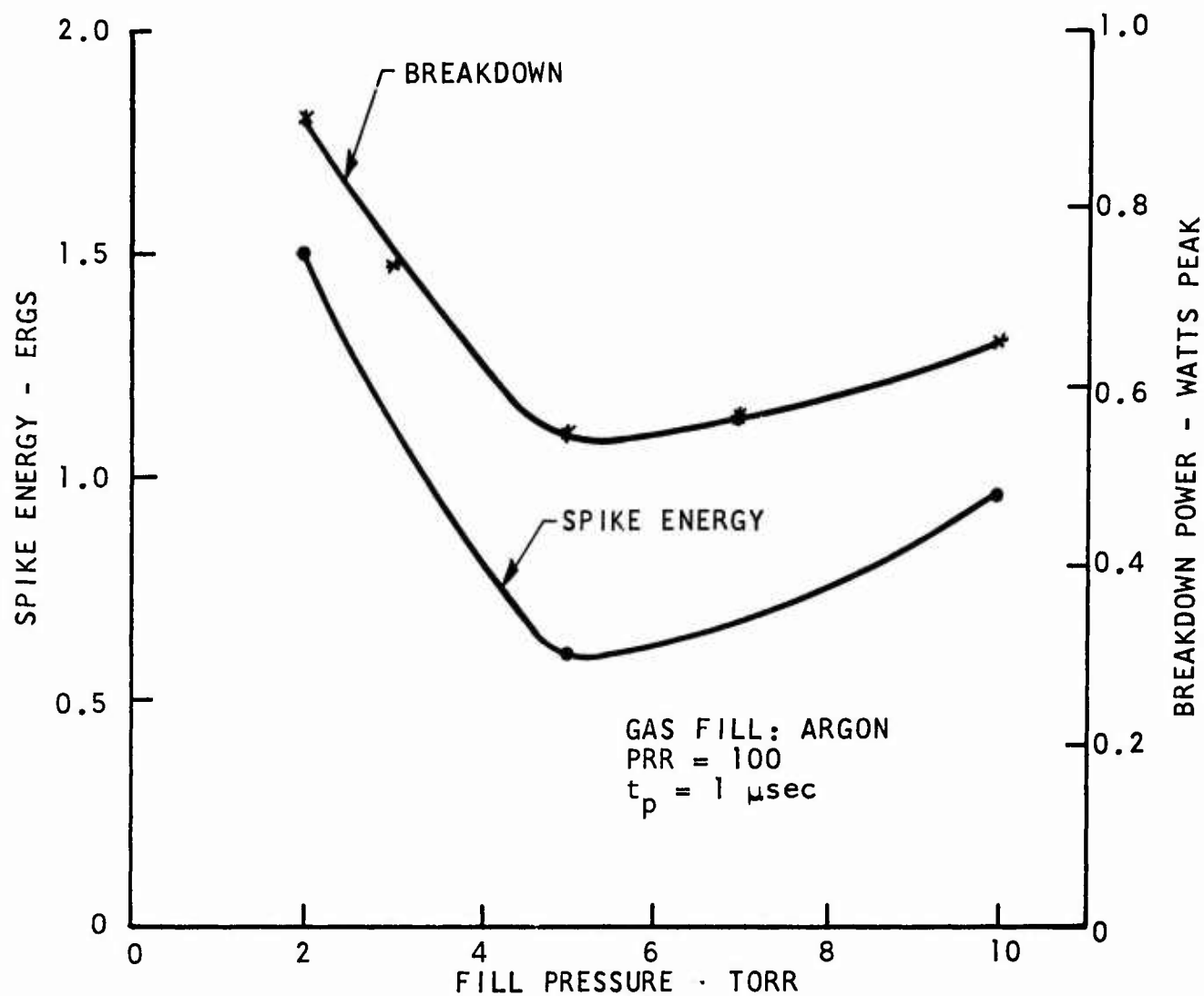S-BAND LIMITER MOUNT

D-4231

FIGURE 5

BREAKDOWN POWER CHARACTERISTICS OF DC AND RA KEEP ALIVES

D-4230

* SPIKE ENERGIES CALCULATED FROM AMPLITUDE AND WIDTH
MEASUREMENTS OBTAINED WITH A TEXTRONIX 1S1 SAMPLING
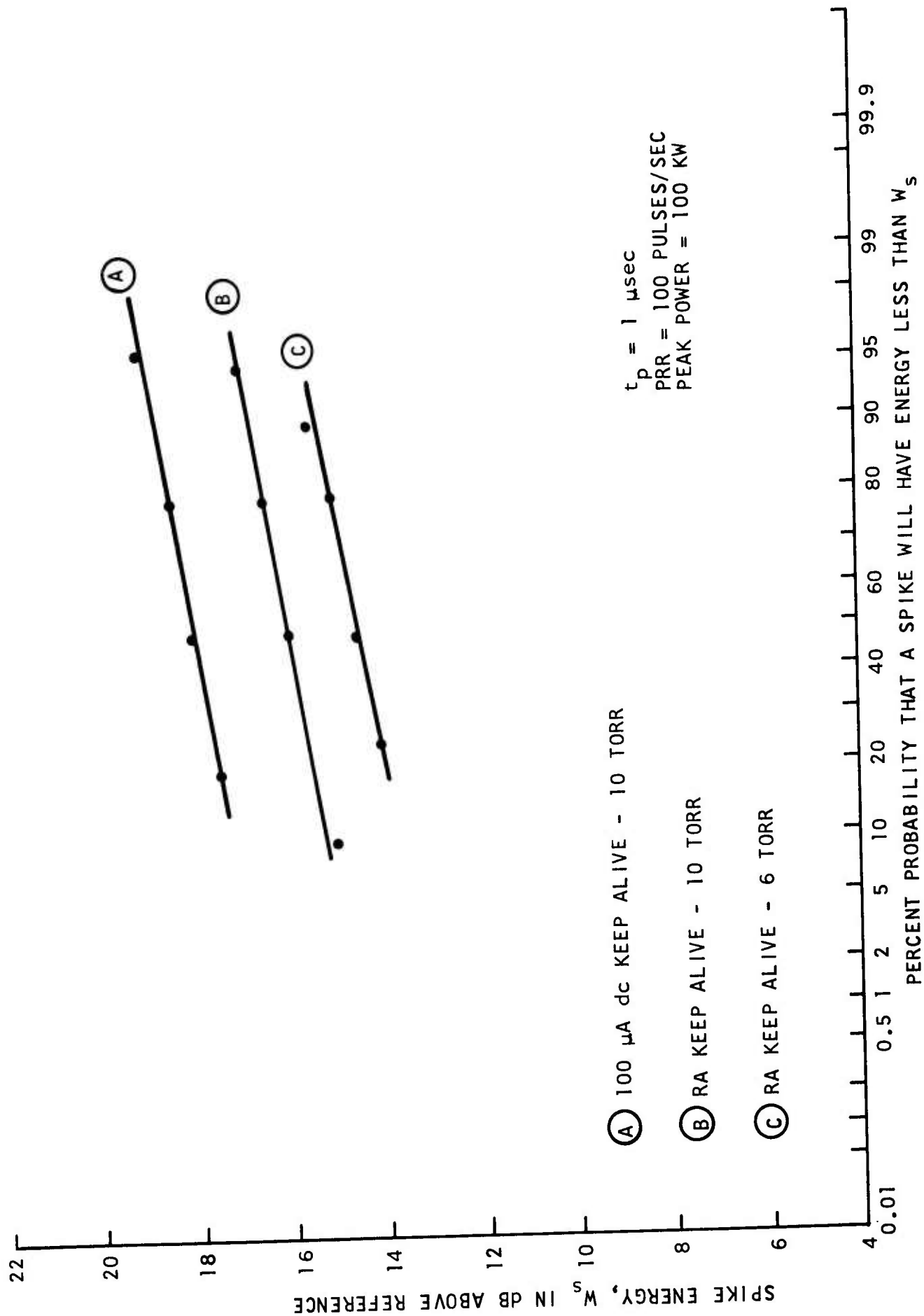OSCILLOSCOPE UNIT.

FIGURE 6

BREAKDOWN POWER AND SPIKE ENERGY* FOR RA KEEP ALIVE

D-4229

FIGURE 7

SPIKE ENERGY DISTRIBUTION

t_p = 1 μsec
PRR = 100 PULSES/SEC
PEAK POWER = 100 KW

Ⓐ 100 μA dc KEEP ALIVE - 10 TORR

Ⓑ RA KEEP ALIVE - 10 TORR

Ⓒ RA KEEP ALIVE - 6 TORR

PERCENT PROBABILITY THAT A SPIKE WILL HAVE ENERGY LESS THAN W_s

SPIKE ENERGY, W_s, IN dB ABOVE REFERENCE

D-4228